A GREENHOUSE GAS INVENTORY FOR MONTGOMERY COUNTY, MD

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1. INTRODUCTION

The scope of this project is to conduct an inventory of greenhouse gas (GHG) emissions sources for Montgomery County, MD for 1993-2001, forecast GHG emissions for the years 2002-2010, and evaluate select emissions reduction measures in the context of the county's emission reduction goal. By completing an inventory, Montgomery Co. joins over 130 local governments in the United States addressing climate change.

The project is being performed as an Independent Research Project for course credit towards a Master's Degree in Environmental Science and Policy at Johns Hopkins University's Advanced Academic Programs. It is a collaboration with the Montgomery County Department of Environmental Protection (DEP) and, which has committed to a series of steps to manage its GHG emissions under the International Council for Local Environmental Initiative's (ICLEI) Cities for Climate Protection (CCP) program.

2. BACKGROUND

2.1 Climate Science

Climate change is an issue of major environmental, social, and economic significance. It is caused primarily by increasing atmospheric concentrations of greenhouse gases (GHGs) such as carbon dioxide, methane, and nitrous oxide. While the effects of these gases are not yet completely understood, the conclusion of the majority of the scientific community is that human activity is resulting in global warming.

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and ozone (O3). Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) are GHGs emitted solely by human activities. CO2, CH4, and N20 are continuously emitted and removed from the atmosphere by natural processes. However, anthropogenic activities can release or sequester large quantities of these gases, changing their global average concentration. Scientists have shown that this effect can have both positive and negative feedback effects on natural systems.

To quantify the relative "radiative forcing" of various greenhouse gases, the Global Warming Potential (GWP) is used. It is defined as the cumulative forcing effect over a specified time horizon resulting from the emission of a unit (mass) of gas relative to a reference gas (CO2). GWP values allow policy makers to compare the impacts of emissions and reductions of different gases (even though, according to the International Panel on Climate Change, GWPs have an average uncertainty of ±35 percent)[1].

Evidence that climate change is affecting the way many Americans live and work is accumulating. As a result, Montgomery County, MD is taking steps to address the issue within its borders. A sensible first

[1] The unit, CO2-equivalents (e-CO2), is used here to measure the total radiative forcing effect of the county's GHG emissions. Adopting a single term to describe the cumulative climate impact of multiple gases is a standard convention in GHG inventory development.
http://www.epa.gov/ttn/chief/eiip/techreport/volume08/viiiintro.pdf

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step for the county – and other communities interested in managing their emissions – is to perform a GHG inventory of emission sources.

2.2 The Role of Cities

Action at the local level – by cities, counties, and municipalities – is an important component of the nascent U.S. response to climate change. A surprisingly large number of localities have initiated or planned actions aimed at slowing the growth of atmospheric GHG concentrations and minimizing the present and future impacts of climate change[2].

Cities are important partners in this movement for a number of reasons. First, cities contribute significantly to national GHG emissions (some cities have larger economies and greater emissions than entire countries in the developing world). Second, cities and their constituents can reap the economic benefits of cost-effective policies to reduce emissions. Third, city policy-makers can directly and indirectly influence the type of fuel used to generate electric power at local utilities, and educate citizens about the economic and environmental implications of power-sector fuel choices. Fourth, cities are involved in land use planning, commercial and industrial development, waste management, building codes and standards, and natural resource management. They also have authority over public transport, highway construction, and transportation financing[3].

Despite the important role of cities in addressing domestic GHG emissions, they do not automatically perceive mitigation to be an important policy goal. However, many have concluded that it is. One reason is growing evidence that large-scale impacts will affect local ecosystems, traditions[4], and human health. Communities are also taking action in response to constituent demands for action from local leaders. In public polls, a growing majority of citizens express concern about how current GHG-related decisions will affect future generations[5]. A final reason why cities are addressing emissions is that many urban areas are growing rapidly, which will have an increasing impact on the environment and quality of life for residents.

Once a city makes a commitment to manage its GHGs, the logical first step is to prepare an inventory. This identifies the major emission sources contributing to the city's overall emission profile and produces a baseline from which to measure progress. After completing its GHG inventory, a city may take additional steps, like developing an action plan to achieve emissions reductions. To date, over 130 cities have prepared GHG emission inventories and action plans, and begun to implement targeted programs and policies[6].

It is important to remember that preparing a community-level GHG inventory is a voluntary activity with no regulatory significance. (In contrast, state-level inventories of criteria air pollutants are regulated under the Clean Air Act[7].) Because GHG emissions are not managed by the federal government, inventories act instead as a prelude to voluntary GHG reductions. This means it is practical for most cities to use an emissions accounting methodology that provides a "back-of-the-envelope" emissions estimate with a higher level of uncertainty than found in criteria air pollutant inventories.

2.3 Cities for Climate Protection

The ICLEI Cities for Climate Protection (CCP) program began in 1993 as a global campaign to reduce anthropogenic GHG emissions and air pollution. The program is active in local governments in North

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[2] http://www.epa.gov/globalwarming/visitorcenter/publicofficials/course.html
[3] Ibid.
[4] Shorter ski seasons and lower levels of maple sugar production are two potential disruptions.
[5] http://www.harrisinteractive.com/harris_poll/index.asp?PID=108
[6] Young, Abby (ICLEI). Personal communication. 3 July 2002.
[7] http://www.epa.gov/oar/oaqps/peg_caa/pegcaain.html

America, Europe, and Africa, where it promotes GHG mitigation and associated co-benefits[8]. Under CCP, communities voluntarily commit to implementing ICLEI's milestones and form local partnerships with the appropriate organizations. Cities then conduct a GHG inventory, set a GHG reduction target, and outline how it will be achieved in a "Local Action Plan." Here are ICLEI's five milestones:

Milestone 1. Conduct an energy and emissions inventory and forecast. The inventory profiles energy use and GHG emissions for a base year (1990 or 1995 are suggested), and estimates growth in emissions for a target year, typically 2010 or 2015. It applies to: (a) municipal operations, including buildings, facilities, and waste streams, and (b) the wider community, including residential and commercial buildings, transportation, and industry (assuming data is available).

Milestone 2. Establish an emissions target. Adopting a target, and timetable for its achievement, is essential to foster political will and create a framework that guides the planning and implementation of measures.

Milestone 3. Develop and obtain approval for an action plan. This document outlines a strategy to reduce GHG emissions, synthesizes the emissions analysis, provides a rationale for the target and timetable, and describes the policies and measures the local government will pursue to achieve the target. Ideally, the action plan incorporates public awareness and education campaigns, as well as direct GHG reduction measures.

Milestone 4. Implement policies and measures. This step implements measures to reduce GHG emissions. It typically occurs after the development and approval of the action plan, though it may occur before or during the plan's design phase.

Milestone 5. Monitor and verify results. Monitoring and verification of progress on action implementation is an ongoing step that begins once measures are implemented. It is formalized with the approval of the action plan. The Torrie-Smith software package assists in the quantification of emissions reductions and allows for uniform reporting of emissions reductions to ICLEI on a biennial basis[9].

2.4 Montgomery County Context

Like other participants in ICLEI's CCP program, Montgomery County is a high-density urban area with a high GHG to land-area ratio. It is home to nearly 30,000 businesses and several major transportation corridors, including I-95 and I-270. The population has grown from about 757,000 in 1990 to 873,341 in 2000. Montgomery County is 491 square miles in area, so there are – on average – 1779 people per square mile. This makes Montgomery County the State of Maryland's most populous jurisdiction. It is also Maryland's most affluent, with an average personal income of $45,595 (compared to the state average of $32,517 and national average of $28,546). The labor force consists of 482,985 people working primarily in information technology, telecommunications, biotechnology, software development, aerospace, and various professional services. There are also 19 federal agencies operating locally. Montgomery County's climate – another factor that affects GHG emissions – is characterized by hot summers and cold winters. The average summer temperature is 73.8ºF and the average winter temperature is 35.0ºF. Annually, there are 4,784 heating degree-days and 1,019 cooling degree-days in the county[10].

The economic, demographic, and climatic realities in Montgomery County underscore challenges and opportunities with respect to GHG management. It is likely that the sectors emitting most of the county's GHGs are where efforts to reduce emissions can potentially be most effective. For example, while transportation is a major economic activity and GHG emitter within Montgomery County, it also presents

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[8] http://www.iclei.org
[9] http://www.iclei.org/us/
[10] http://www.choosemaryland.org/assets/document/w02%20Montgomery.pdf

mitigation options (e.g., fuel switching, transportation alternatives, carpooling, etc.)[11]. Similarly, the high density of local office space suggests that adopting building codes for energy efficiency could be a major opportunity to reduce emissions. Since green space in urban areas has been demonstrated to improve the quality of life for residents, planting trees could double as a carbon sequestration and heat island mitigation measure.

2.5 Potential Climate Change Impacts in Montgomery County

According to a recent study by the Joint Global Change Research Program at the University of Maryland, “Maryland has many assets that depend upon climate, in direct and indirect ways[12]. These assets may be at risk from climate change depending on how we prepare for the future.” The paper notes that, at first glance, it seems the Baltimore-Washington corridor – which includes Montgomery County – would not be vulnerable to climate change. This is because the region’s economy is not heavily dependent on natural resource-oriented activities like fishing, farming, recreation, and food processing, which are readily affected by climate instability. On the contrary, UMD researchers found that while the county’s urban-oriented economic base (e.g., services, trade, transportation, healthcare, etc.) may be less vulnerable than economies in other parts of the state, there are several areas of potential vulnerability.

For instance, according to the Maryland Emergency Management Administration, the B-W corridor has a high risk of drought, extreme heat, tornado, and thunderstorms, each of which are predicted to increase under plausible climate change scenarios (Figure 1).

	High Risk	Medium-High Risk
Drought	Frederick, Montgomery, Howard, Carroll, Baltimore City and County, Harford	None
Extreme heat	Baltimore City	Frederick, Prince George’s, Charles, Calvert, Howard, Anne Arundel, Harford
Flash/River Flooding	Frederick	Montgomery, Carroll, Baltimore County, Anne Arundel
Thunderstorm	Frederick, Montgomery, Anne Arundel	Prince George’s, Carroll, Howard, Baltimore County, Harford
Tornado	Frederick, Anne Arundel	Prince George’s, Charles, Carroll, Baltimore County, Harford
Winter Weather (snow and ice)		Frederick, Montgomery, Prince George’s, Anne Arundel, Howard, Carroll
Tidal/Coastal Flooding		Anne Arundel, Calvert

Source: Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000.

Figure 1

High-intensity precipitation could, in turn, cause combined sewage overflows and pathogen loading in drinking water systems. Health impacts from waterborne diseases might result (though it is possible that these are controllable by existing public health systems). The most frequent climate-induced water resource problems are predicted to be power outages, which affect pumping capacity. If, as predicted, increased heat events occur in the B-W corridor, the heat island effect would be exacerbated. This causes an increase in poor air quality, ground-level ozone concentrations, and public health-related problems. Local health could also be affected by higher rates of asthma and other respiratory diseases

[11] http://www.pnl.gov/globalchange/projects/vul/Mdatrisk.pdf
[12] http://www.pnl.gov/globalchange/projects/vul/Mdatrisk.pdf

linked to fine particulates in the lower atmosphere. This would increase health care and health insurance costs, and could even make the region a less desirable place to live. If this occurred, tax revenues would decline and "quality-of-life" would suffer. The latter is often cited in firms' decisions about where to locate. Climate-induced impacts to surrounding areas would also affect the recreation and vacation opportunities of B-W corridor residents, which are also valued by businesses and their employees. Harming these assets could therefore have negative effects on economic development within the B-W corridor.

3. THE EMISSIONS INVENTORY

3.1 Inventory Background

Organizations and individuals conducting GHG inventories are often united by concern about climate change. However, stakeholders may have very different uses for the emissions data they contain. Scientists, for example, use emissions inventories as tools to develop atmospheric models. Policy makers use inventories to develop strategies and policies for emissions reductions and to track their progress. Regulatory agencies and corporations rely on inventories to establish compliance with legal emission rates. Businesses, the public, and other interest groups use inventories to better understand the sources and trends in emissions.

A well-constructed inventory is consistently prepared, accurate (relative to its intended purpose), and thoroughly documented. It typically includes the following information:

- Identity of the gases or pollutants
- Type and level of activity that causes emissions
- Time period over which the emissions are estimated
- Geographic area covered[13]

Methods for developing greenhouse gas inventories are continuously evolving and improving, and many recent developments in inventory methodology have emerged. For example, EPA now publishes its *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2000*, WRI has initiated a new corporate emissions protocol, and the IPCC's Gas Inventory Program recently issued their *Good Practice in Inventory Management* document.

3.2 Torrie-Smith Cities for Climate Protection Software

Cities participating in the CCP program use a Windows-based software package to account for their GHG emissions. The software, developed by Torrie-Smith Associates, Inc., was launched in 1997 and updated in 2001. It is designed to be a user-friendly tool to assist city and county governments in the development of local-level GHG inventories and action plans for reducing emissions. The software has four main components – two support inventory and action plan development at the "community" level and two support the same function at the level of government, or "corporate", operations. (As noted above, the scope of this analysis is limited primarily to conducting a community and corporate inventory. A proposed wind power purchase is also evaluated in the context of the county's goal and projected emissions. Additional measures will be evaluated in the GHG action plan that is planned for early 2003.)

The Torrie-Smith software facilitates:

- Accounting for both community and corporate greenhouse gas emissions from electricity use, direct fuel consumption, waste production, and "other" emissions – a separate module for tracking emissions that do not fall into the previous categories – across the commercial, residential, industrial, and transportation sectors
- Quantifying financial savings and air pollutant reductions from GHG emission reduction strategies

[13] http://www.epa.gov/ttn/chief/eiip/techreport/volume08/viiiintro.pdf

- Importing user-defined electricity use emission factors for more accurate, county-specific measurements of emissions and emission offsets from GHG reduction measures[14]

The overall emissions calculation methodology employed by the Torrie-Smith software is “top down,” rather than “bottom up.” This means, for example, that CO2 emissions from vehicles are estimated using community-level vehicle miles traveled (VMT) data rather than information on the number and type of vehicles in the county, average gasoline consumption for each vehicle-type, and carbon content of the fuels. Values for these parameters are captured in the software as default coefficients. Using a top-down technique simplifies the calculation of GHG and criteria air pollutant emissions by relating pollutant emissions (e.g. CO2, NOx, etc.) to the quantity of fuel combusted. This approach allows CCP users to spend less time on research and data collection, which for busy local officials is an important feature. The software guidance suggests that, to the extent more accurate local information is available, user-defined coefficients should be used.

3.3 Inventory Scope

3.3.1 What’s Counted?

This inventory accounts for GHG emissions from on-site fuel and electricity consumption in Montgomery County’s residential, commercial, and industrial sectors, as well as emissions from transportation. Emissions from industrial and commercial activities are combined into a single category labeled “commercial.”[15] Accounting for industrial and commercial emissions together is necessary because the source-data provides one set of activity data for both sectors. Determinations of whether to include emission sources in the inventory were driven primarily by data availability and contribution to the total (i.e., emissions sources making up a small – about 5% or less – percentage of the total were not counted).

3.3.2 What’s Not Counted?

Using these criteria, a number of minor emission sources are excluded. For example, methane and nitrous oxides from agricultural activity in Montgomery County are not counted because the relevant data is unavailable and because calculations are resource intensive. Emissions of “high-GWP” gases – like HFCs, PFCs, and SF6 – from industrial processes are not included either. This is because there is limited high-GWP-emitting industry in the county, and because this data if not readily obtainable. Sequestration of carbon dioxide by trees and vegetation is not counted either. This is because the appropriate county-level data is not available and the methodology for measuring agricultural carbon fluxes is complicated, data-intensive, and difficult to interpret[16]. While measuring carbon sequestration is beyond the scope of this inventory, the fact that portions of Western and Upper Montgomery are forested make it likely that a considerable quantity of carbon is absorbed in the county. It sequestered emissions were measured, they would be subtracted from the overall county emissions total, acting as a counter-weight to the climate impact of fuel combustion.

3.3.3 GHG Emissions From Electricity Use and On-Site Fuel Consumption

The majority of GHG emissions in Montgomery County are attributable to fossil fuel combustion – for electricity generation, on-site use, and automobile use – and are readily measurable. Emissions from

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[14] Where software defaults are replaced with user-defined values, users are encouraged to document the activity (i.e., fuel consumption and waste generation) data and emission factors. This ensures maximum transparency and accuracy, and allows for third-party verification of results to enhance transparency. Thorough documentation also permits future refinement and the opportunity to pool data with nearby CCP cities in a regional inventory.

[15] This naming decision reflects the fact that commercial activity accounts for a much larger percentage of overall GHG emissions in Montgomery County than does industrial activity.

[16] http://www.eia.doe.gov/oiaf/1605/gg99rpt/land.html#ludi

electric power – the largest source of both community and corporate level emissions – are "assigned" to the electricity's end-user, rather than the power generation facility itself. Accounting for these "indirect" emissions makes it possible to demonstrate how electricity-consuming activities occurring within the boundaries of Montgomery County are directly responsible for GHG emissions, regardless of whether the physical emissions occur in the county or not. Making the connection between electricity-consuming activities and the resulting (off-site) emissions is an important step in emissions management.

Default coefficients that relate GHG emissions to kilowatt-hours (kWh) of electricity are provided in the CCP software. These figures are based on the Department of Energy's Reporting Guidelines for the Section 1605(b) greenhouse gas emissions reporting system (*Voluntary Reporting of Greenhouse Gases, Instructions for Form EIA-1605*). However, because these coefficients do not reflect interstate and international flows of electricity, this analysis used user-defined emissions factors derived from E-Grid data.

E-Grid (the Emissions & Generation Resource Integrated Database) is an EPA project that describes the environmental characteristics of all electric power generation in the US[17]. It accounts for cross-border power flows by providing GHG emissions information at the regional power pool level[18]. This is an important distinction because the emissions profile of power plants *operating in a state* is not the same as the emissions profile of electricity *end-use in that state*. Since all states import and/or export power, the emissions coefficient from in-state electricity consumption is different from the coefficient of in-state generation. This difference is theoretically equal to the electricity-consumption-weighted average of the state's emissions coefficient and the coefficient of the state(s) to and from which power flows. In reality, however, the precise quantity of interstate electricity flows is unknown and therefore cannot be calculated. Relying on factors calculated from E-Grid therefore results in a more accurate assessment of Montgomery County's electricity-based environmental impact than Torrie-Smith's default state factors.

Default (Figure 2) and E-Grid CO2 (Figure 3) coefficients are shown below in short tons of CO2-equivalent (e-CO2). User-defined coefficients were only defined for CO2, so the other GHGs (N20 and CH4) and air pollutants (SOx, CO, and VOC) in Figures 2 and 3 are identical. E-Grid-based annual CO2 coefficients were derived as follows: for the years 1996 and 1998 they are pre-calculated in the database. For the other years shown, a manual calculation in Microsoft Excel was necessary. This was accomplished by adding up total CO2 from Mid-Atlantic Area Council (MAAC) states – MD, DE, PA, and dividing by total kWh of electricity consumed. For the year 1991, this was 1.55 lbs/kWh for the entire MAAC region. The 1996 and 1998 emission rates are given in E-Grid for the MAAC region as 1.34 and 1.19. The intervening years of 1992-1995, as well as 1997, were extrapolated, giving coefficients of 1.508, 1.466, 1.424, 1.382, and 1.27 kWh, respectively. Converting lbs/kWh to tons C02 per million BTU results in the coefficients shown in the first column of Figure 2[19].

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[17] http://www.epa.gov/airmarkt/egrid/

[18] Power pools are responsible for safety and reliability within the regional electric system, facilitate open access to transmission, and serve the hub for power and energy markets where utilities buy and sell electricity. Maryland is a member of the Mid-Atlantic Area Council (MAAC), http://www.maac-rc.org/.

[19] This was accomplished by: (1) determining the number of kWh per million BTU (i.e., 3411.8), weighing the resulting term by the observed E-Grid emission factor (in lbs/kWh), and dividing by short tons (e.g., 2000 lbs.).

	(tonseCO2/million Btu)			(tons/million Btu)			
Year	CO2	N2O	CH4	NOx	SOx	CO	VOC
1993	2.16E-1	8.76E-4	6.13E-5	5.19E-4	1.24E-3	3.24E-5	3.81E-6
1994	2.18E-1	8.81E-4	6.17E-5	5.23E-4	1.24E-3	3.29E-5	3.83E-6
1995	2.08E-1	8.59E-4	5.15E-5	5.04E-4	1.15E-3	2.91E-5	3.17E-6
1996	2.09E-1	8.76E-4	5.11E-5	5.10E-4	1.18E-3	2.82E-5	3.16E-6
1997	2.15E-1	8.96E-4	5.30E-5	5.23E-4	1.21E-3	2.94E-5	3.28E-6
1998	2.16E-1	8.84E-4	5.81E-5	5.21E-4	1.23E-3	3.13E-5	3.60E-6
1999	2.16E-1	8.76E-4	5.93E-5	5.18E-4	1.22E-3	3.19E-5	3.68E-6
2000	2.16E-1	8.76E-4	5.93E-5	5.18E-4	1.22E-3	3.19E-5	3.68E-6
2001	2.16E-1	8.76E-4	5.93E-5	5.18E-4	1.22E-3	3.19E-5	3.68E-6

Figure 2

	(tonseCO2/million Btu)			(tons/million Btu)			
Year	CO2	N2O	CH4	NOx	SOx	CO	VOC
1993	1.95E-1	8.76E-4	5.11E-5	5.10E-4	1.18E-3	2.82E-5	3.16E-6
1994	1.89E-1	8.76E-4	5.11E-5	5.10E-4	1.18E-3	2.82E-5	3.16E-6
1995	1.83E-1	8.76E-4	5.11E-5	5.10E-4	1.18E-3	2.82E-5	3.16E-6
1996	1.79E-1	8.76E-4	5.11E-5	5.10E-4	1.18E-3	2.82E-5	3.16E-6
1997	1.73E-1	8.96E-4	5.30E-5	5.23E-4	1.21E-3	2.94E-5	3.28E-6
1998	1.60E-1	8.84E-4	5.81E-5	5.21E-4	1.23E-3	3.13E-5	3.60E-6
1999	1.60E-1	8.84E-4	5.81E-5	5.21E-4	1.23E-3	3.13E-5	3.60E-6
2000	1.60E-1	8.84E-4	5.81E-5	5.21E-4	1.23E-3	3.13E-5	3.60E-6
2001	1.60E-1	8.84E-4	5.81E-5	5.21E-4	1.23E-3	3.13E-5	3.60E-6

Figure 3

Information about the quantity of natural gas, oil, and propane directly consumed on-site at commercial, industrial, and residential facilities was collected from the county's Department of Finance. These "activity data" are multiplied by Torrie-Smith default emission factors for on-site fuel combustion to determine the resulting GHG emissions. The amount of CO2 released by direct fossil fuel combustion is dependent on three variables: (1) the type and amount of fuel consumed, (2) the fraction of the fuel oxidized – the percentage of a fuel's carbon does not oxidize to form CO2 and remains in the elemental form, and (3) its carbon content, which varies by fuel type: coal has the highest carbon content per unit of energy, followed by petroleum – about 80% of that for coal – and natural gas, which is about 55% of coal's carbon content[20]. The first variable is the user defined activity data, while the latter two variables are embedded in the software's default GHG coefficients as follow:

<u>Default GHG Emission Coefficients (tons eCO2/TJ)</u>

	(tons CO2/TJ)	(tons eCO2N2O/TJ)	(tons eCO2CH4/TJ)
Natural Gas	5.59E+01	3.42E-02	1.01E-01
Light Fuel Oil	7.46E+01	2.05E-01	8.01E-02
Propane	7.61E+01	2.05E-01	8.01E-02

[20] http://www.epa.gov/ttn/chief/eiip/techreport/volume08/viii01.pdf

Activity data on electricity consumption and on-site fuel use were also used to estimate criteria air pollutants. Two sources-documents were used to calculate the relevant coefficients: EPA's (2000) AP-42 emissions database[21] and IPCC's *Revised Reporting Guidelines on Greenhouse Gas Emissions*[22]. These sources derive the air pollutant emission coefficients from detailed GHG and atmospheric pollutant emissions databases; criteria pollutant emission coefficients for gasoline and diesel, however, were obtained from EPA's "Mobile 5" model.

Criteria Pollutant Coefficients (in lb/TJ) and Sources

	tons NOx/TJ	tons SOx/TJ	tons CO/TJ	tons VOC/TJ
Natural Gas	8.31E-02	3.50E-04	2.14E-02	8.31E-02
Landfill CH4	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gasoline	4.13E+00	2.08E-01	5.42E+00	4.13E+00
Diesel	5.48E+00	9.35E-01	3.40E+00	5.48E+00
Oil	7.67E-02	5.07E-01	1.94E-02	7.67E-02
Propane	6.29E-02	4.97E-01	1.75E-02	6.29E-02
Green Power	0.00E+00	0.00E+00	0.00E+00	0.00E+00

3.3.4 GHG Emissions From Transportation

GHG emissions from Montgomery County's transportation sector result from the combustion of gasoline and other fuels used to power vehicles. Estimating emissions from the transportation sector in the Torrie-Smith software is based on a "top-down" methodology that simply requires users to input VMT. However, underlying this interface is a built-in calculation that includes assumptions about county VMT, including the number of vehicle-trips, the length of these trips, and the number of people in each vehicle. The software also employs default values for vehicle fuel efficiency and GHG (emissions/unit of fuel) components. This gives the relationship: CO2 = VMT X CO2/VMT.

The VMT term in this equation breaks down as follows: VMT = (person-trips/persons per vehicle) X trip length (km). "Person-trips/persons per vehicle" is the difference between the number of individual trips and the number of vehicle-trips weighted by the number of people in the vehicle. (The vehicle occupancy factor here suggests why transit and car-pooling reduce emissions per passenger mile of travel.) The second term in the equation, CO2/VMT, separates the vehicle fuel efficiency and the CO2 intensity of the fuel used: CO2 per VMT = fuel efficiency (in miles per gallon) X emissions per unit of fuel. Combining these terms leads to the formula for transportation emissions: CO2 Emissions = (A/B) X C X D X E, where:

A = number of person trips made using the vehicle type
B = number of people per vehicle
C = trip length
D = fuel consumption
E = CO2 emissions per unit of fuel

Montgomery County's VMT data was entered into the software's Road Transportation Assistant, which employs default values for the terms above to derive total GHGs from transportation. The Torrie-Smith software assumes that both gasoline and diesel are the primarily fuels used for transportation. To calculate the emission coefficients associated with these fuels, emission coefficients for autos, light trucks, and heavy trucks were derived from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998*[23]. Using information on the types of pollution control devices, averages for the CH4 and N2O emission factors can be calculated for each transportation mode (autos, light trucks, and heavy trucks).

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[21] http://www.epa.gov/ttn/chief/ap42/index.html
[22] Ibid. EPA, 1996.
[23] Ibid. EPA, 2000.

These averages where used in conjunction with the following data from previous research by Torrie-Smith Associates on transportation modes and fuel type:

VMT by Fuel and Transportation Mode

	Autos	Vans/Light Trucks	HeavyTrucks	Total
Gas	61.09%	37.54%	1.38%	100.00%
Diesel	1.27%	7.99%	90.74%	100.00%

This data can is then used to calculate CH4 and N2O coefficients for gasoline and diesel. The coefficients depend on emission rates from pollution control types and transportation mode within individual vehicle fleets. The following chart shows the final emission coefficients calculated using the above methods for gasoline and diesel for eCO2 of CH4 and eCO2 of N2O.

Emission Coefficient Calculations

	Gas (eCO2 of CH4)	Diesel (eCO2 of CH4)	Gas (eCO2 of N2O)	Diesel (eCO2 of N2O)
kg/litre	0.00036	0.00013	0.00053	0.00010
kg/GJ	0.01050	0.01520	0.01370	0.00289

Additional default assumptions to calculate GHGs from the transportation sector are described in greater detail in Appendix III at the end of this document.

3.4 Emissions Data Sources

"Activity data" is the term used to characterize the human actions – like driving a car or turning on the lights – that cause GHG emissions. These data were collected from Montgomery County agencies and entered into the Torrie-Smith software. Then they were multiplied by the appropriate emissions coefficient and aggregated at the community and corporate levels to determine total GHG emissions. Activity information comes from a variety of sources, and must be gathered for each year under consideration in the inventory. Data on the following activities were collected from the sources listed here:

- Waste Generation: Montgomery County Dept. of Solid Waste (http://solidwaste.dpwt.com/facilities/rrf_cem.asp)
- VMT: Washington Metropolitan Council of Governments (http://www.mwcog.org/trans.html) and Montgomery County Parks and Planning Commission (http://www.mc-mncppc.org/)
- Electricity Consumption: PEPCO (http://www.pepco.com/) and Montgomery County Dept. of Finance (http://www.co.mo.md.us/services/finance/)
- Direct Fuel Consumption: Washington Gas (http://www.washgas.com/) and Montgomery County Dept. of Finance (http://www.co.mo.md.us/services/finance/)

4. RESULTS

Total community GHG emissions, measured in short tons of eCO2, for Montgomery County during the period 1993-2001 are shown in Figure 4. The graph demonstrates: the relatively constant allocation of total emissions among the sectors over time, a sharp peak in the total in 1996, and a gradual rise from 1998 to the present. The sectoral distribution of emission in Montgomery County is comparable to that of the US, though direct comparisons are difficult because of accounting discrepancies (e.g., the US inventory accounts for direct GHGs from industry, agriculture, and other emissions-related activities like natural gas flaring, which are not accounted for in Montgomery County)[24].

The 1996 peak is the result of a particularly cold winter in which residents and businesses relied on additional fossil fuel consumption for space and water heating. GHGs have been rising slowing since 1998 due to economic growth, an increase in VMT – without a concomitant increase in fuel economy – and a growing population.

The same scenario is also portrayed in terms of emissions by fuel-type (Figure 5). Indirect emissions from electric generation are the largest contributor, while the remaining fuels represent direct, on-site combustion in the residential and commercial/industrial sectors. The fuels used to generate electricity are not shown on the graph, but are embodied in the total. The generation resource mix of electrical power consumed in Montgomery County is approximately 47% coal, 37% nuclear, 9% natural gas, 4% oil, 1.3% hydro, and 1.2% biomass. This means that, on average, 97.5% of Montgomery County's electricity comes from fossil fuel, with the remaining percentage coming from renewable resources[25].

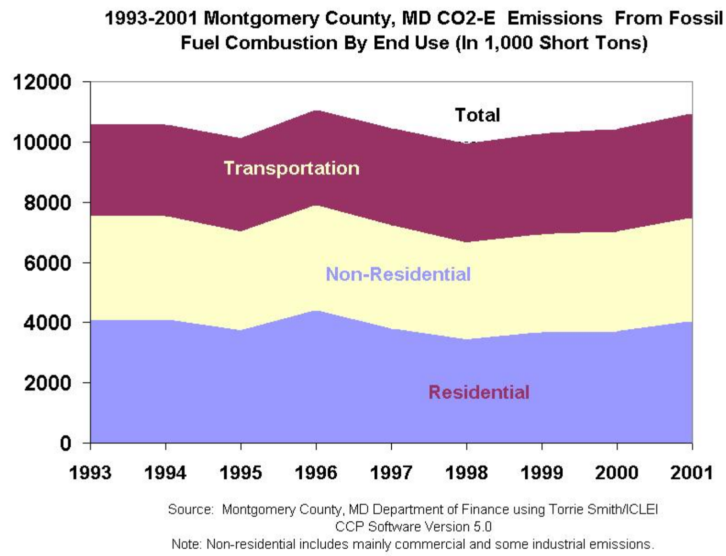

Figure 4

[24] http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsUSClimateActionReport.html
[25] http://www.epa.gov/airmarkt/egrid/

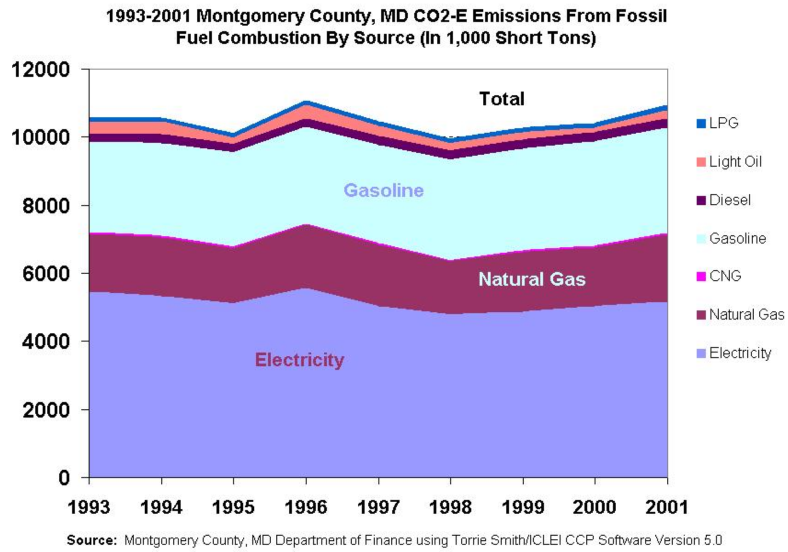

Figure 5

Within the State of Maryland, Montgomery County accounts for approximately 10% of overall GHG emissions (see Figure 6). This comparison uses the British thermal unit (BTU), an English standard unit of energy, as a proxy for GHGs. The graph therefore provides a rough estimate of county-versus-state climate impact. The 10% emission figure is substantial, though low with respect to a weighted state population average. Since 16% of Maryland's population resided in Montgomery County in 2000, per capita emissions in the county are comparatively low[26]. The county's BTU consumption data used here was calculated under the "community" module of the Torrie-Smith software.

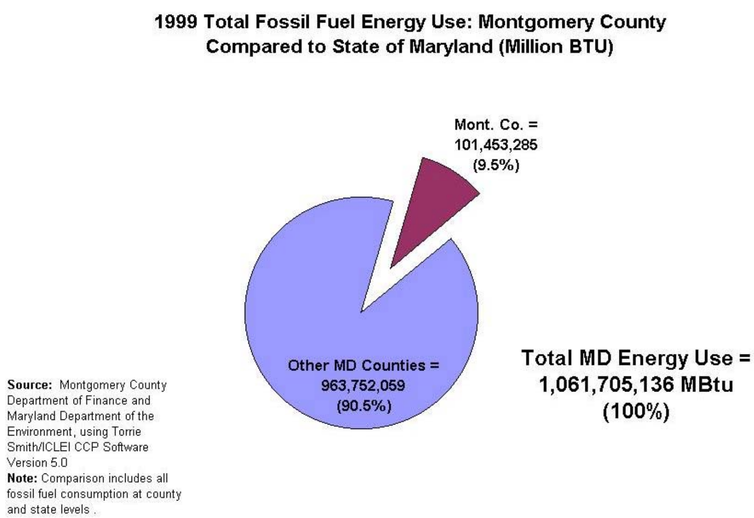

Figure 6

Figure 7 shows the trend in CO2-equivalent emissions, total personal income (TPI), and population in Montgomery County from 1993-2000. It also illustrates how emissions intensity – which is measured here in emissions per capita and emissions per unit TPI – has changed over time. The graph illustrates that CO2 emissions fluctuated significantly in the 1990's (though the positive and negative changes

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[26] http://quickfacts.census.gov/qfd/states/24000.html

approximately cancelled each other out), population has increased at a nearly linear rate[27], and TPI has increased steadily. Since the county's CO2 emissions are de-coupled from population and income, measuring GHG intensity suggestes that efficiency gains have taken place. It appears that during the 1990's in Montgomery County, factors putting upward pressure on emissions have been offset by an equivalent downward pressure. At the national level this counter-weight is typically cited as the effect of technology. While this may also be the case in Montgomery County, there may be other important (but unidentified) mitigating factors at work.

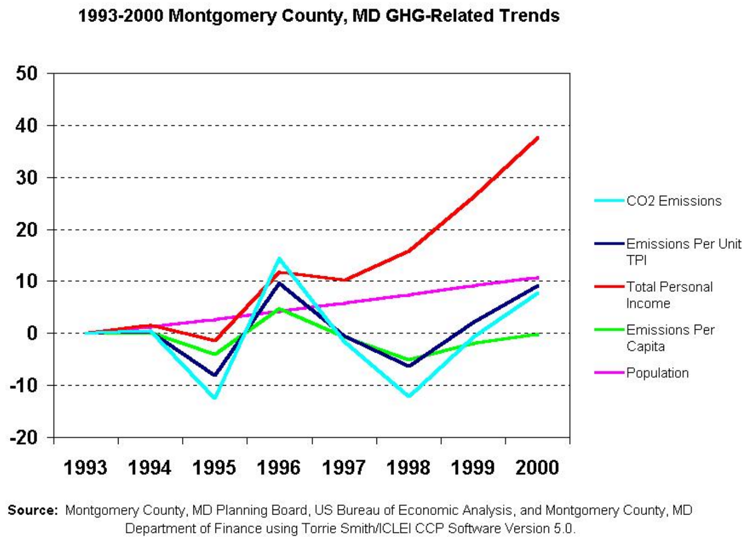

Figure 7

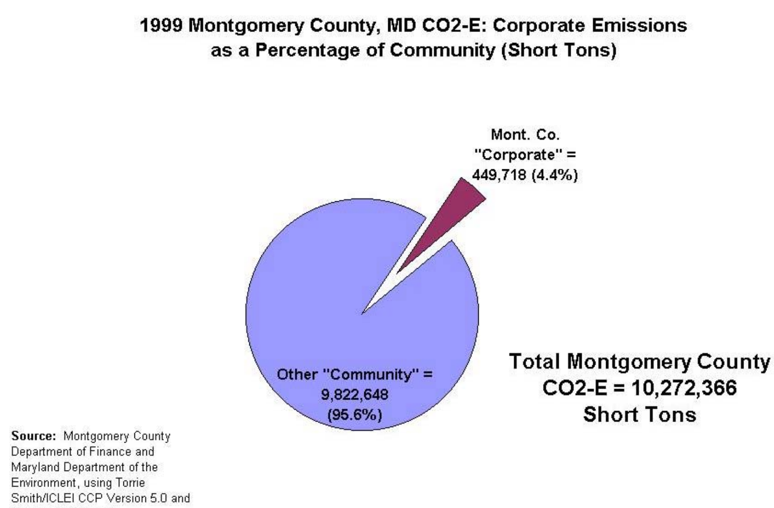

Figure 8

Montgomery County GHG emissions are calculated at the community and corporate levels. The former refers to total county GHGs, and the latter is a subset representing emissions from county facilities and

[27] Historical population data exists for 1990, 1995, and 2000, and the intervening years were interpolated.

operations. This analysis is undertaken primarily to illustrate the percentage of emissions under direct control of county managers. In the action plan phase of ICLEI's CCP program, many participants opt to focus their initial efforts on GHG management strategies at the corporate level. A comparison of the magnitude of community and corporate emissions are shown in Figure 8. Overall GHGs from the county's facilities and operations are about 4.5% of the community total. While this is a small amount in the context of the state and county totals, it nonetheless represents an emissions reduction opportunity that county officials may wish to pursue.

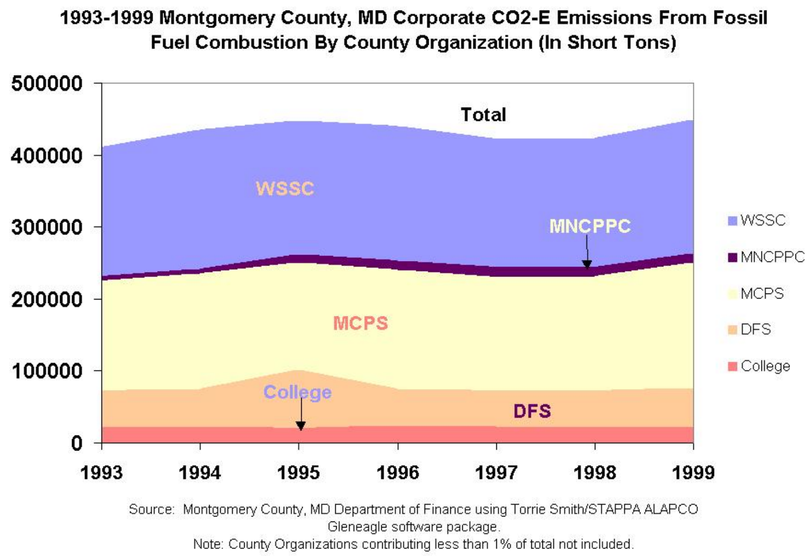

Figure 9

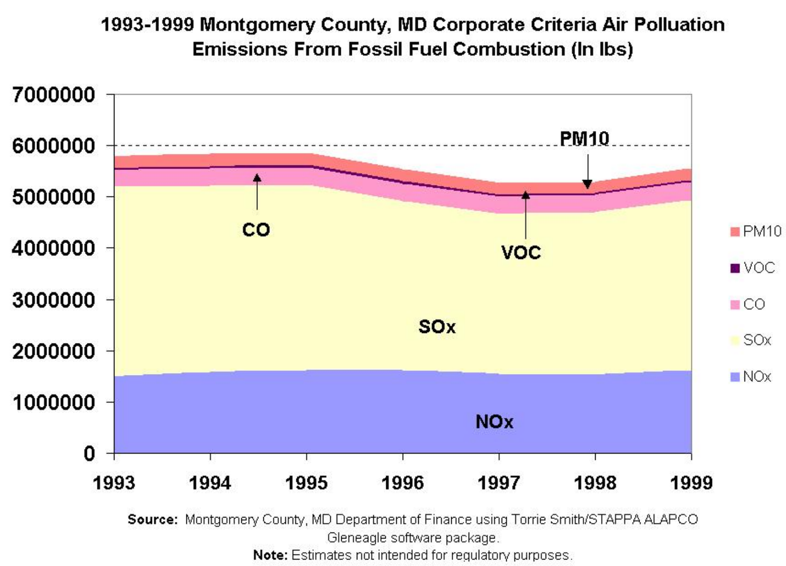

Figure 10

County facilities that contribute significant quantities to the corporate GHG total include: Montgomery County Public Schools, Montgomery College, Maryland-National Capital Park and Planning Commission, Department of Facilities Services, and Washington Suburban Sanitary Commission. The extent to which county organizations can cost-effectively reduce GHGs dependents on several operational factors, including the number and type of energy efficiency and conservation measures already in place. For this reason, baseline determination can be a primary determinant of a local government's ability to achieve additional emission reductions vis-à-vis a published target. GHG emissions at county facilities from the baseline year of 1993 to 1999 are shown in Figure 9. The corresponding level of air pollutant emissions are shown in Figure 10.

5. EMISSIONS MANAGEMENT

5.1 Community Emissions Goal

Montgomery County's Department of Environmental Protection (DEP) recently set an emissions reduction goal of 20% below 1990 levels by the year 2010[28]. The DEP website states this goal publicly at: http://www.co.mo.md.us/services/dep/Energy/climate.htm. The county has already taken several steps to achieve it, and a number of others are planned. Figure 11 provides a graphical illustration of the GHG reduction goal and how it differs from a business-as-usual projecttion of emissions. The yellow bars provide a hypothetical, linear schedule for achieving the reductions. A GHG action plan – ICLEI CCP program's third milestone – will be underway soon, and will go into greater detail on mitigation scenarios.

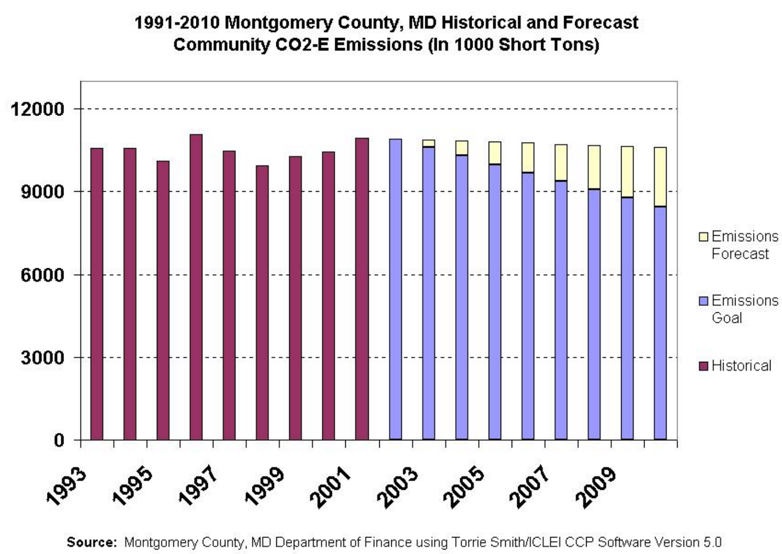

Figure 11

5.2 Emissions Forecast

Both community and corporate GHG emissions forecasts were completed for Montgomery County for the years 2002-2010. Future emissions were calculated on the basis of historical data using the average of the annual emission changes for the period in which data exists (1990-2001 for the community analysis and 1993-2001 for the corporate analysis). This number was then used to extrapolate emissions from 2002 to 2010. The average annual change in corporate emissions from 1990-2001 projects that GHGs will contract from 2002-2010 by about 1% annually. The average rate of change in community emissions from 1993-2001 also projects that future emissions will decrease – again, by a rate of slightly less than 1% per year. Since community and corporate emissions tracked one another, the historic approach to estimating future emissions projects similar trends into the future.

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[28] This goal may need to be revised,as community inventory data only goes back 1993.

Like all GHG forecasts, this methodology is subject to considerable uncertainty. One reason is that many of the factors affecting short- and long-term emission trends are not easily predictable. In the short run (5 or so years), the key determinants of overall emissions are: (1) unexpected changes in retail energy prices, (2) divergence in the relative prices of natural gas and coal in electricity generation, and (3) unusual summer or winter weather. Over the long term (20 or so years), emissions are determined mainly by: (1) changes in technology, (2) trends in the mix of industrial and commercial activity, and (3) developments in government policy[29]. While considerable resources at the national and international levels are devoted to predicting how these factors will change over time, projecting emissions remains a great challenge.

A shortcoming of the historical projection methodology used here is that it does not explicitly consider how the determinants of future emissions will change over the relevant period. Instead, the projections rely solely on historic data based on past energy prices, fuel mix, and weather events. Another source of uncertainty in the Montgomery County projections is that future emissions were calculated using a top-down approach that aggregated emissions across sectors. In reality, emissions in different sectors change independently of one another, suggesting that a bottom-up methodology incorporating assumptions about individual sectors is preferable. An additional shortcoming is that using historic data precludes accounting for the interaction and feedbacks among the determinants of GHG emissions.

Despite these uncertainties, the historic approach used in this analysis is not an invalid estimation tool. Rather, it implies that the assumptions and methodology should be stated up-front when projection figures are cited to ensure transparency and avoid misinterpretation. It is also worth noting that because the projection period is relatively short-term, the factors determining the accuracy of the historic data approach are limited to those that can change quickly: overall energy prices, relative price of competing fuel sources, and weather. This means that the forecast methodology used in the Montgomery County context need not account for projections of technology change, industry mix, and government policy.

At the national level, projection tools – like the National Energy Modeling System (NEMS) used at Department of Energy – attempt to account for both short- and long-term considerations, as well as the interactions among them. However, this type of analysis is expensive and unnecessary for Montgomery County's purposes.

5.3 Emissions Reduction: Proposed Corporate Wind Purchase

Government officials in Montgomery County are investigating the purchase of a large block of wind energy that would be generated at the Backbone Mountain Wind Farm in Pennsylvania. If a contract can be successfully negotiated, the price premium for wind energy would be between $0.016-$0.018 per kWh for a 5% commitment. The premium depends on contract length, which decreases as contract length increases (wind costs $0.016 extra under a five year deal). The estimated aggregate annual cost to the county under a 1-2 year commitment to purchase 5% of its total power from wind is $468,339; a 3-5 year commitment costs $442,320 per year; and a 5+ year commitment costs $416,302 per year. On a per-ton of CO2 basis, this amounts to about $19/ton in the first two years (2003-2004) and $18/ton CO2 in the subsequent three years (2005-2007). These projections are subject to change, depending the terms of the wind-purchase contract, the magnitute of future corporate electricity consumption, and other factors. GHG and criteria air pollutant emission reductions from supplying 5% of total corporate electric demand from wind have been estimated and are shown in Figure 12.

The resulting GHG emission total for corporate operations is calculated by subtracting 5% of projected emissions from the total for the years out to 2010. Since wind energy results in no GHG emissions, the resulting offset is determined by a simple calculation. However, the total magnitude of the offset (in terms of GHG reductions) cannot be precisely determined, as it is based on a percentage of total projected emissions rather than purchasing a discrete quantity of electricity. Thus, the accuracy of

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[29] http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsUSClimateActionReport.html

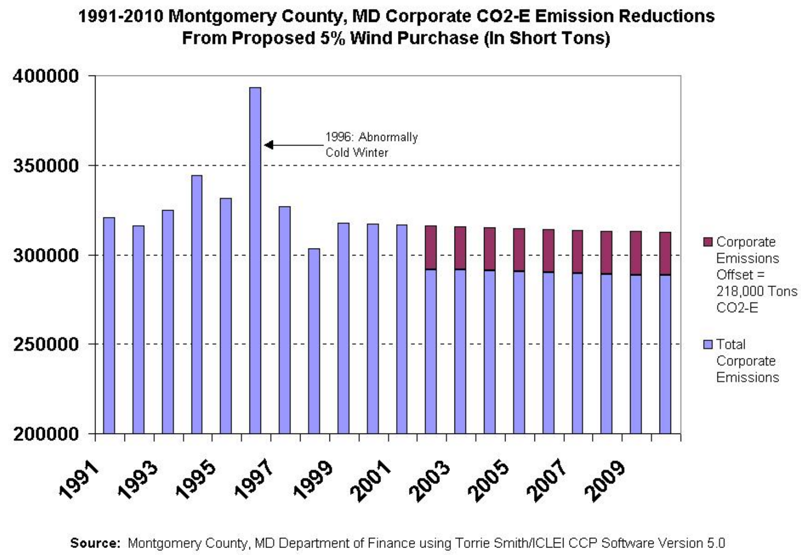

Figure 12

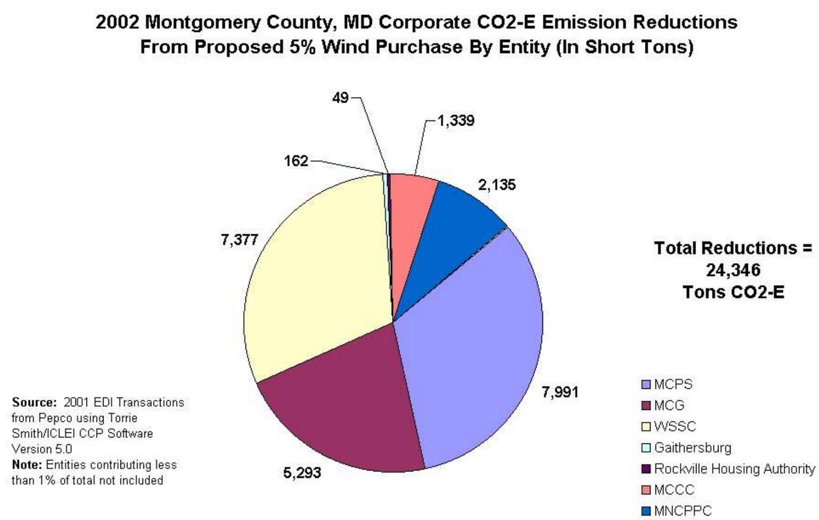

Figure 13

the projected wind offset depends on the accuracy of the corporate emissions projection (see emissions forecast section above), which was calculated from historical average changes in emissions during the 1990's. This means that the actual amount of the offset will deviate from the projected quantities by an amount that is dependent largely on unforeseeable events and circumstances affecting the demand for fossil fuel.

Another way in which the quantity of GHGs offset from wind could differ from projected figures is if the emission factor for calculating offsets is inaccurate. The procedure for determining the emission factor for calculating the climate change benefit of purchasing renewable energy is a "marginal unit" approach based on the capacity factors of electric generating plants. The methodology estimates how much of each plant's generation is likely to be affected by renewable energy measures by evaluating the plant's fuel type and capacity factor. This approach is preferable to using an "average emissions rate" –

because average emissions are not correlated with direct emissions, and baseload generation is rarely displaced – but there is still considerable uncertainty in the resulting offset calculations. (See Appendix II for a more detailed discussion of how marginal emission reductions are calculated here.)

6. QUALITY CONTROL

A series of quality control steps were taken in the areas of data collection, activity data, emission factors, and overall emissions calculation to minimize errors during the development of the Montgomery County inventory. As defined by the IPCC's *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*[30], the goals of quality control include ensuring data integrity, correctness, and completeness, and identifying and addressing errors and omissions.

6.1 Activity Data Collection and Handling

During the data gathering and collection phase, several steps were followed to minimize errors, identify areas for refinement, and ensure the replicability of results:

- Where certain data fields within an emissions source category were complete, a consistency check was performed to ensure that similar fields were complete for the entire inventory period.
- In source-categories lacking data, further investigation determined whether this information was readily available and could be credibly estimated. An assessment of whether the category was a significant contributor to overall emissions in Montgomery County, and whether accurate emission factors and activity data were available, was performed.
- Because activity data from spreadsheets were manually entered, a thorough data review was performed to minimize transcription errors. This is necessary because activity data cannot be electronically imported into the Torrie-Smith software. All input data was checked at least once for consistency with source spreadsheets. (In contrast, larger state or national-level inventories may rely on checks of representative data samples.)
- Source data documentation is provided to allow for independent replication of results. This includes detailed record keeping with documentation of references, methods, data sources, individual contacts, and other relevant information. Transparent information handling allows others to evaluate the underlying assumptions and use source activity data and emission factors to replicate results.

6.2 Emission Factors

Both default emission factors (embedded in the Torrie-Smith software) and specified regional factors are used to assess overall GHGs in Montgomery County. The latter were adopted to more accurately predict electric power generation and to determine emission reductions from energy efficiency and renewable energy. Default factors were used for other sources of emissions, including direct fuel consumption, transportation, and waste.

- As the default emission factors used to calculate emissions from direct fuel consumption are the most recent available and based on established and widely-accepted figures from the Energy Information Administration (EIA), no action was taken to further refine them. The factors used to calculate emissions from waste and transportation were similarly unaltered.
- Where regional factors were used to determine emissions from power plants, E-Grid factors were used. These account for power flows across state boundaries and for this reason are generally considered more accurate than state-specific emission factors. These were checked for transcription accuracy to ensure they were properly imported into the software.
- There is substantial work being done at EPA and elsewhere to improve the factors used to calculate emissions reductions from renewable
- The calculations used to determine the appropriate factors for the Mid-Atlantic Area Council (MAAC) were quality checked.

[30] http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

6.3 Emissions Calculations and Results

Several checks were performed to ensure that accurate final emissions estimates were calculated for each source-category. This was performed to prevent mathematical errors and to ensure accurate emission factors, activity data, and other parameters:

- Results from an emissions source category for a given year were compared with results from previous and subsequent years (and compared to other source categories) to ensure no substantial deviation from expected values. The assumption was that aggregated results should make sense in the context of trends and existing knowledge in each source-ategory.
- Source-category emission comparisons that appeared unreasonable were re-visited and checked for accuracy in emission factors and activity data. If these parameters were accurate, the possibility that an exogenous event caused the anomaly was explored. (For example, comparatively large eCO2 emissions from natural gas in 1996 turned out to be the result of an abnormally cold winter.)

Other specific data checks included:

- An evaluation of historical inventory data for large changes in emission magnitudes over periods of several years
- An order-of-magnitude check on the activity data to identify outlying calculation inputs
- An assessment of imported (region-specific) emission factors to identify significant deviation from the software default values

7. CONCLUSION

With this analysis, Montgomery County, MD's completes the first milestone of ICLEI's Cities for Climate Protection program. Because the county previously set its emissions goal, two of the five ICLEI milestones are now complete. In addition, there are plans to begin work on the third milestone, a GHG action plan, in January 2003. This project will identify emissions reduction opportunities at county facilities and operations, and across the community at-large. Proposed emissions reductions measures will be quantified to assess their GHG-offset potential, and to identify their contribution towards achieving the county's emissions goal. The action plan will add to the prospective corporate wind power analysis above by evaluating energy efficiency options for the residential and commercial sectors, as well as measures targeting the transportion sector.

Another "next-step" is to reconcile the 1990 emissions goal with the fact that historic, county-level data only goes back to 1993. One remedy is to backcast total GHGs from 1993 to 1990; another is to set a new goal with respect to 1993, for which historic data is available. In addition, further analysis is needed in the waste sector. Total GHGs from waste generated in the county will be quantified in Januray prior to the development of the action plan. Due to the existence of a methane collection system at one county landfill, and a waste-to-energy facility at the other, total emissions from waste will be comparatively small. Lastly, the county should initiate work to integrate this analysis – and the upcoming action plan – into parallel initiatives taking place in nearby counties and at the state level. There are a number of steps being planned by local NGO's, the state energy and environmental departments, the Unviersity of Maryland, and others to assess and take action on GHG emissions.

APPENDIX I: MENU OF GHG REDUCTION MEASURES[31]

Make building energy improvements. Municipal buildings represent a substantial opportunity to achieve cost-effective reductions in local greenhouse gas emissions. Copiers, fax machines, computers, scanners, exit signs, heating and cooling products, windows, and other equipment with the Energy Star label save money while reducing energy-related greenhouse gas emissions and other air pollution.

Change traffic lights to light-emitting diode (LED) fixtures. LEDs are 80-90 percent more efficient and last 10 times longer than ordinary lights, reducing energy and maintenance costs.

Use renewable energy systems. Switching from fossil fuel-generated electricity to renewable-based power is an effective way to reduce greenhouse gas emissions and other air pollution.

Purchase green power. In cities where competitive electricity markets exist, utilities and other electricity retailers may offer customers the option to purchase "green" renewable-generated power.

Foster employee trip reduction programs. Working at home or at a telecommuting center reduces vehicle miles traveled and associated air pollution and GHG emissions.

Replace motors in city operations with more efficient models. Energy-efficient motors can slash energy consumption, reduce greenhouse gas emissions and other air pollution, and save money.

Redesign communities to encourage walking, biking, and mass transit. Every gallon of gas burned by a vehicle releases 20 pounds of CO2 to the atmosphere, and vehicles are major contributors to urban air pollution.

Provide incentives for mass transit or carpooling. City governments can implement market measures to influence automobile use.

Convert fleets to run on alternative fuels. Using vehicles that run on fuels such as compressed gas, ethanol, methanol, biodiesel, hydrogen, and electricity can improve urban air quality and reduce greenhouse gas emissions.

Put police on bicycles. Many municipal police departments have cut the number of vehicles in their fleet by instituting "Cops on Bikes" programs. These initiatives save vehicle, fuel, and maintenance costs, and typically improve the departments' ability to serve and protect citizens.

Initiate "Pay As You Throw" waste disposal programs. Charging residents for the collection of household trash based on the amount they throw away creates a direct economic incentive to recycle more and generate less waste. Reducing the amount of trash sent to landfills can lower methane emissions.

Implement curbside recycling. Recycling can save energy by reducing the fossil fuels needed to extract and manufacture new products and, in the case of paper products, increase carbon sequestered in forests. Recycling also diverts paper, cardboard, and other organic materials from landfills, where they would otherwise decompose and produce methane.

Recycle office paper and reduce landfill costs. Recycling reduces the energy and materials needed to produce new paper. Methane emissions also are decreased by diverting paper from landfills.

Buy products made from recycled materials. Recycled products typically require less energy to produce than new products, and many recycled products cost less than new ones. Items such as recycled plastic lumber also may reduce the user's installation and maintenance costs.

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[31] http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BVQXM/$File/smartsavingsclimatesolutionsforcities.pdf

Establish composting programs. Composting organic wastes reduces methane emissions and diverts waste from landfills.

Capture methane from landfills. Decomposing trash in landfills produces landfill gas, which is about 50 percent methane. Methane also can be a reliable and money-making fuel.

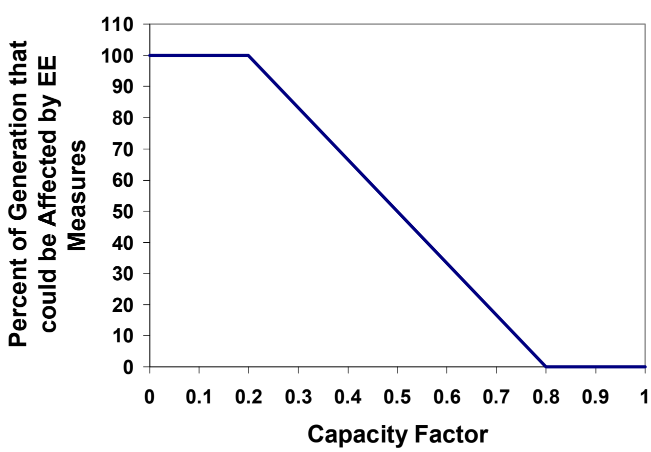
Integrate Smart Growth in planning. Smart Growth is metropolitan development that pays for itself while protecting air and water quality, encouraging redevelopment of former industrial sites (brownfields), and promoting community economic vitality and livability.

Plant trees to keep buildings and streets cooler to improve air quality, lower air-conditioning loads, and save money. Trees provide shade for buildings and streets, reducing the amount of energy needed to cool buildings.

Use highly reflective surfacing and roofing materials. Highly reflective roofs and pavements can help make cities cooler, reduce the formation of smog (which is dependent on air temperature), reduce air-conditioning loads, and save money. Highly reflective roofs and surfaces can reduce home or building owners' air-conditioning bills by 10 to 50 percent.

APPENDIX II: METHODOLOGY FOR QUANTIFYING MEASURES

This methodology estimates how much of each plant's generation is likely to be affected by renewable energy measures. Instead of using dispatch modeling, these values are determined by using the plant's fuel type and capacity factor. First, the generation from nuclear and hydroelectric plants are assumed to not be affected by renewable energy measures. Nuclear units are normally baseload units (among the first units to be dispatched to accommodate electricity demand). Hydroelectric plants are also generally baseload units and generate electricity whenever adequate supplies are available. Capacity factor is a measure of a plant's generation relative to its maximum capacity over a given period of time and is generally a value between 0 and 1. E-Grid lists plant specific capacity factors on an annual basis. In this method, plants that have a capacity factor of 0.8 or greater are considered to be baseload units and none of their generation would be affected by energy efficiency measures. In this method, plants that have a capacity factor of 0.2 or less are considered to be "peaking" units and all of their generation would be affected by renewable energy measures. The following figure illustrates the relationship between capacity factor and how much of each plant's generation could be affected by renewable energy measures.



The resulting factor for each plant is applied to the 1998 generation, resulting in the amount of generation from each plant that could be affected by renewable energy measures. Each of these figures is multiplied by the plant-specific CO2 emission rate to estimate emissions in pounds. The generation and emissions are summed for all of the plants in the MAAC area. The total emissions are divided by the total generation figure as described above to determine the overall rate[32].

APPENDIX III: VEHICLE TYPE, FUEL EFFICIENCY, AND OCCUPANCY FACTOR

The following vehicle fuel efficiencies are the default values used in the transportation modulue of thte Torrie-Smith software. These values were decided in consultation with numerous US transportation sources, are are stated in miles per gallon. Default occupancy factor and fuel for each vehicle are also shown:

Fuel	Car	Motorcycle	Bus	Light Truck	Heavy Truck
Gasoline	31	73.7	5	20.8	12.6
Diesel	38.7	91.7	6.2	25.9	9.4
Propane	25.2	59.8	16.9	7.9	
Default Occupancy Factor	1.6	1	10	1.6	1.6
Default Fuel	Gas	Gas	Diesel	Gas	Diesel

APPENDIX IV: ABBREVIATIONS

Btu	British thermal unit
CAAA	Clean Air Act Amendments of 1990
CCP	Cities for Climate Protection
CFC	Chlorofluorocarbon
CH4	Methane
CO2	Carbon dioxide
DEP	Montgomery County's Department of Environmental Protection
DFS	Department of Facilities Services
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
ECO2	Carbon dioxide equivalent emissions
EIA	Energy Information Administration, U.S. Department of Energy
EIIP	Emissions Inventory Improvement Program
EPA	U.S. Environmental Protection Agency
GDP	Gross domestic product
GHG	Greenhouse gas
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
ICLEI	International Council for Local Environmental Initiatives
IEA	International Energy Association
KWH	Kilowatt-hours
LFG	Landfill gas
LPG	Liquefied petroleum gas
MAAC	Mid-Atlantic Area Council
MC	Montgomery College
MCPS	Montgomery County Public Schools

[32] Diem, Art (Environmental Protection Agency). Personal communication. 29 July 2002.

MMTCE	Million metric tons carbon equivalent
MNCPPC	Maryland-National Capital Park and Planning Commission
MSW	Municipal solid waste
N2O	Nitrous oxide
NEMS	National Energy Modeling System
NOx	Nitrogen oxides
PFC	Perfluorocarbon
SOx	Sulfur oxides
TPI	Total personal income
TJ	Terajoule
VMT	Vehicle miles traveled
VOC	Volatile organic compound
WSSC	Washington Suburban Sanitary Commission